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Estimation of the water quality of the Izhevsk Reservoir tributaries by macrozoobenthos indicators

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Abstract. The species composition and quantitative indicators of macrozoobenthos of the main tributaries of the Izhevsk Reservoir were studied. The status of the rivers was assessed by bioindication methods. A significant simplification of the structure of the benthic communities in the lower reaches of the Luk and Podborenka rivers has been established. The Podborenka River is the most polluted of the tributaries of the Izhevsk Reservoir, and therefore, it is an important source of the deterioration of water quality in there.

1. Introduction

For many years, the water quality of the Izhevsk Reservoir has been causing concerns of environmentalists, officials, and citizens. For the first time, an intense algal bloom of water was recorded in 2003. Since then, a set of environmental measures has been carried out to improve the ecological condition of the reservoir. These include major repairs of the spillway of the Izh River hydroelectric complex, cleaning the bottom of the reservoir from sediments, strengthening the banks, utilization and processing of the JCS Izhstal slag dump, construction of the embankment in the city center, algolization, stocking with plankton-eating fish species and removal of phytomass of higher aquatic plants in shallow and heavily overgrown areas of the upper reach.

However, the tributaries of the reservoir, as permanent sources of unorganized wastewater discharge, are still not given due attention. At the same time, small rivers pollute the Izhevsk Reservoir with biogenic and mineral suspended substances, since there is a high economic activity in the catchment area. Only in 2020, cases of fish deaths caused by the ingress of municipal wastewaters into the river water were recorded on two tributaries (the Luk and the Pazelinka)

The rivers Izh, Luk, Pazelinka, Shaberdinka and Pionersky Creek flow into the upper part of the reservoir. The Podborenka and Malinovka rivers flow into the lower reach of the reservoir. Its catchment area is in residential and industrial areas of Izhevsk.

The purpose of this work is to assess the water quality of the main tributaries of the Izhevsk Reservoir by macrozoobenthos organisms.

The main hydrological indicators of rivers are given in table 1.

The Izh River is formed by the confluence of the Bolshoy and Maly Izh rivers. Its source is located near the village of Malye Oshvortsy on the border of the Igrinsky and Yakshur-Bodinsky districts of the Udmurt Republic. The river flows through Udmurtia and Tatarstan towards a north-south and flows into the Kama River 124 km from its mouth. The total length of the Izh River is 259 km, of which 70 km is the length of the river from the source to the dam of the Izhevsk Reservoir.



Table 1. Characteristics of the main tributaries of the Izhevsk Reservoir.

The tributary	Length, km	On the territory of Izhevsk	Forest cover, %	Waterlogging, %	Flow rate, m/sec	Basin area, km ²
The Izh River, upstream the reservoir	70	35.0	87	3	0.12 - 0.15	1640
The Luk River	39.0	5.0	50	3	< 0.3	355
The Pazelinka River	12.8	12.8	18	1	0.07–0.63	70
The Malinovka River	5.7	2.5	52	0	0.2-0.4	8.2
The Podborenka River	4.9	4.9	36.3	0	0.03–0.68	13.4

The Luk River is a right tributary of the Izh River. The river begins in a swamp located 2.2 km northeast of the village of Dintem-Vam'ya in the Uvinsky district [1]. The river basin is characterized by developed agricultural production.

The Malinovka River is a right tributary of the Izh River. The source of the river is located 0.5 km west of the village of Malinovo. The river flows through the south-western outskirts of the city of Izhevsk between the microdistricts «Malinovaya Gora» and the village of Varaksino in the Zavyalovsky district.

The Pazelinka River is a left tributary of the Izh River and flows into the Izhevsk Reservoir. The area of the estuarine thickets is 0.17 km². Floating vegetation grows along the banks.

The Podborenka River is a left tributary of the Izh River, which flows into the reservoir near the city embankment. The river valley is one of the first inhabited places in Izhevsk where 62.6% of the catchment area is built up with various industrial and residential facilities.

2. Materials and methods

The Samples on the Izh River were taken from 2011 to 2014. For comparability, this paper provides data on a section of the river with a length of 20 km above the reservoir. The study of macrozoobenthos of the Luk, Malinovka, Podborenka and Pazelinka rivers was carried out from June to September 2019-2020. Samples were taken with a hydrobiological scraper and a DAK-100 ponar samplers. A total of 169 samples of zoobenthos were collected.

During the laboratory processing of the materials, the species composition of macrozoobenthos was determined (chironomids were determined up to subfamily level), the abundance and biomass, the Woodiwiss biotic index [2], the Pantle-Bucke saprobity index [3], the Goodnight-Whitley oligochaete index [4], the Shannon-Weaver species diversity index [5], and Pielou's evenness [6] were calculated. Statistical data processing was performed using the Statistica 10 software package.

Due to the non-normal distribution of data, nonparametric comparison methods for multiple variables (the Kruskal-Wallis ANOVA & Median test) were used for statistical analysis.

To minimize the statistical type I error the Bonferroni correction was introduced which was found by dividing the initial significance level p (0.05) by the number of comparison groups (5). The differences were considered significant if p values were ≤ 0.01 .

3. Results

The studied section of the Izh River has sandy and stony-sandy soils with silt along the banks. The average organic matter content in the bottom sediments was 3.95%. In total, 138 species of invertebrates were recorded at 4 stations, including 25 species of mollusks, 11 species of worms, 19 species of mayflies, 16 species of caddisflies, 2 species of crustaceans and 1 species of stoneflies.

In the headwaters of the Pazelinka River, the soils are clayey, in the middle parts the soils are sandy-silty. Down the river in the zone of water retention by Izhevsk Reservoir, the flow rate is

approximately 0.15 m/s, an overgrowth of the riverbed with macrophytes and the accumulation of detritus at the bottom are observed. The proportion of organic substances in the soil is from 2.2 to 35%. In the benthos 108 macroinvertebrate species have been recorded, including 12 species of worms, 22 of mollusks, 2 of crustaceans, 7 of mayflies, 14 of caddisflies, and two species of freckles in the sources.

The lower course of the Pazelinka River is characterized by the abundant development of thicket fauna, which was studied in detail by I. A. Kargapoltseva in 2011. The average number of invertebrates in the estuarine area of the river Pazelinka varied from 7854.2 to 25463.7 specimens/kg, the average biomass - from 12.1 to 27.9 g/kg [7].

In the Podborenka River, sandy and sandy-silty soils predominate, the content of organic substances in the bottom sediments varied from 2 to 18 %. During two years of research, 68 species of macrozoobenthos were registered. The number of species is dominated by mollusks and beetles - 11 species each. The fauna of oxyphilic species is poorly represented as following: caddisflies – 5 species, mayflies - 3 species, stoneflies were not found.

The following types of soils were identified on the Luke River: clay, silty, silty-sand, sand-detritus, and sand-stony. The content of organic substances in the bottom sediments varied from 3.9 to 22.3%. A total of 91 species of macrozoobenthos were found. Among them, the number of species is dominated by Diptera larvae (15 taxa) and mollusks (14 species). Mayfly larvae are represented by 11 species, caddisfly larvae by 10 species, stoneflies were not observed.

The Malinovka River is regulated by a cascade of three ponds built for the domestic needs of the citizens and ensuring fire safety. The proportion of organic matter in the river bottom sediments varies mosaically, depending on the river flow rate, sampling depth, and the projective coverage of macrophytes. In 2019, it varied from 1.5% to 8.1%.

In 2019, 88 species of macrozoobenthos were identified in the Malinovka River. According to the number of taxa, the dominant groups are dipterans (21 taxa), gastropods (20 species), beetles (12 species), caddisflies, and oligochaetes by 7 species, respectively. Mayfly larvae are represented by 5 species, and stoneflies by one species.

4. Discussion

The bottom biocenoses of the studied rivers were characterized by a rich and diverse fauna, which includes all the main taxonomic groups of macrozoobenthos: annelids, gastropods and bivalves, crustaceans, and insects.

The largest number of species of benthic invertebrates was found in the Izh River (138 species). The Pazelinka River also had a high species diversity (108 species), and the minimum number of species was found in the Podborenka River (68) (Table 2). Also, the sum of the species of the «rheophilic complex» (stoneflies, mayflies and caddisflies) was significantly varied. It ranged from 36 species on the Izh River to 8 species on the Podborenka River.

The total number of macrozoobenthos in the surveyed river biocenoses ranged from 50 specimens/m² (in the mouth of the Podborenka River) to 3488 specimens / m² (in the silt-detritus soil of the Izh River). The abundance of the bottom population depends on the depth and type of bottom sediments [8]. Under anthropogenic pressure, pollution becomes an important factor in the development of benthos. In general, undisturbed biotopes were characterized by a higher population than communities experiencing anthropogenic stress and communities of psammophilic ripal communities.

The total biomass of macrozoobenthos ranged from 0.35 (in the psammophilic community of the Podborenka River contaminated with petroleum products) to 78.06 g/m² (in the lower course of the Malinovka River). The biomass was primarily determined by the presence of bivalves and gastropods in the community. According to the saprobity index (S), the studied rivers can be classified into three types. The source of the Pazelinka River belongs to the oligosaprobic zone, in the middle course it belongs to the β -mesosaprobic zone and at place of its confluence into the reservoir it belongs to the α -mesosaprobic zone. The studied part of the Izh River and the Malinovka River belong to the β -

mesosaprobic zone and are characterized by moderate water pollution. The waters of the Podborenka and Luk rivers belong to the boundary of the β - and α -mesosaprobic zone, this is the transition from moderately polluted to polluted waters. Two sections of the Podborenka River pass into a polysaprobic (dirty) zone due to the impact of the city. The reduction in the number of rheophilic macrozoobenthos species and the mass development of limnophilic polysaprobic oligochaete species and larvae of the *Chironomus* mosquito-ringers indicate an ecological regression in the structure of bottom communities [9], [10].

River sections where macrozoobenthos communities are characterized by the Shannon information diversity index from 1.0 to 2.0 bits/ex according to the V. A. Yakovlev gradation [11] are considered polluted. All the rivers studied have such sections, but the lowest average index is in the Podborenka River (1.15 bits/ex).

The Goodnight Whitley oligochaete index varied mosaically according to the types of bottom sediments and reached the absolute maximum of 90.9% on the Podborenka River. The average values of the oligochaete index are highest in the bottom communities of the Luk River (42.32%), which indicates anthropogenic eutrophication of the stream [12]. The Woodiwiss biotic index also indicates the critical state of the Podborenka River and the deterioration of the ecological state in the lower reaches of the Luke River (Table 2).

Table 2. Indicators of macrozoobenthos of the tributaries of the Izhevsk Reservoir.

River	The Podborenka River	The Pazelinka River	Section of the Izh River	The Luk River	The Malinovka River
Indicators					
Number of macrozoobenthos taxa	68	108	138	91	88
The EPT Richness Index	8	23	36	21	13
The Shannon index(range. average)	0.30-1.80 1.15	1.33-2.17 1.75	0.94-3.04 2.22	0.69-2.43 1.83	0.7-2.4 1.52
Pielou's index	0.19-0.94 0.74	0.78-0.83 0.81	0.41-0.96 0.79	0.4-0.97 0.80	0.33-0.87 0.67
The Woodiwiss Index	1.0-6.0 3.78	6.0-7.0 6.50	5.0-9.0 7.73	2.0-8.0 5.69	5.0-9.0 6.9
The Pantle–Buck saprobity index	2.02-3.6 2.85	1.28-2.67 1.98	1.61-2.32 1.93	1.68-2.84 2.25	1.75-2.2 1.89
The Goodnight-Whitley index	0-90.91 27.71	0-40.71 20.36	0-37.3 5.05	2.1-72.9 42.32	0-10.0 3.52
Biomass. g/m ²	0.35-4.81 1.89	17.25-25.52 13.62	1.67-64.84 19.17	0.68-26.44 12.12	1.98-78.06 22.14
Density. specimens/m ²	50.10-622.22 302.75	566.66-1255.55 911.105	265.20-3488.80 1659.48	400.30-1555.4 908.52	266.7-3200.0 1738.1

Statistical analysis showed a significant difference between the Podborenka River and the Izh and Malinovka rivers in terms of density, biomass, species richness of macrozoobenthos (Fig. 1), saprobity and Shannon indexes ($p < 0.001$).

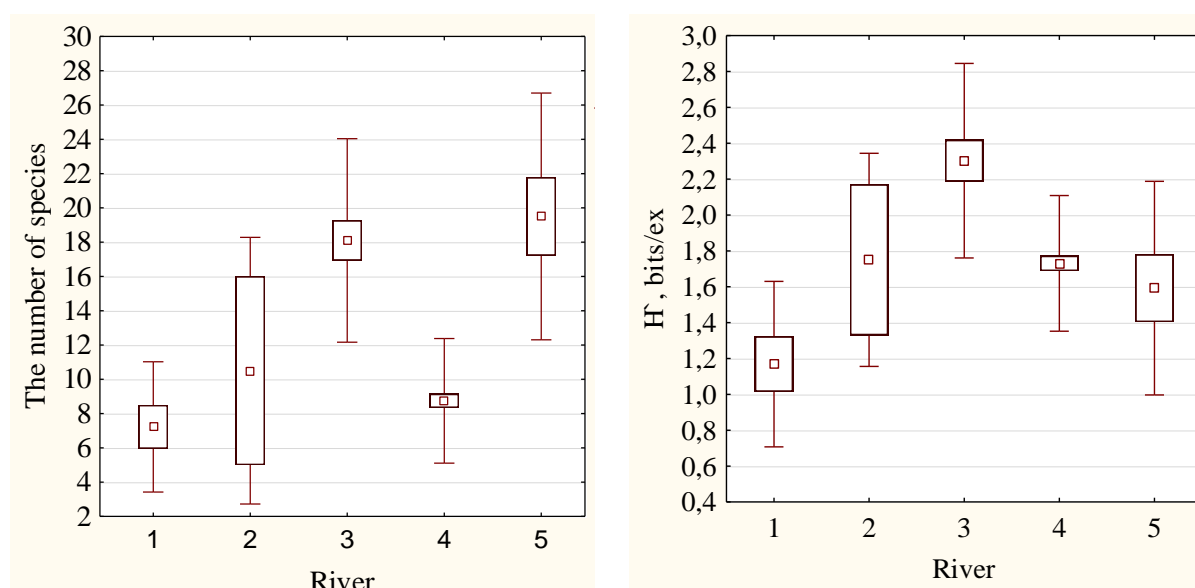


Figure 1. Comparison of rivers by the number of macrozoobenthos species and the Shannon index (a measure of the Kruskal-Wallis rank analysis of variance) (1 – The Podborenka, 2 – The Pazelinika, 3 – The Izh, 4 – The Luk, 5 – The Malinovka).

The Luk River significantly differs from the Izh and Malinovka rivers in terms of density, biomass, and the number of benthic species ($p < 0.001$). According to the Shannon index, the Luke River significantly differs from the Podborenka and Izh Rivers (figure 1).

5. Conclusions

According to the results of the conducted studies, the water quality in the studied tributaries of the Izhevsk Reservoir belongs mainly to the 3rd and 4th class of water quality. With the increase in anthropogenic load, the sanitary condition in the lower reaches of the Luk and Podborenka rivers deteriorates. Statistical analysis of the data showed a significant difference between the Podborenka River and the Izh and Malinovka rivers in terms of density, biomass, and species richness of macrozoobenthos in the saprobity and Shannon indices ($p < 0.001$). The Podborenka River is the most polluted of the tributaries of the Izhevsk Reservoir. This means that it is an important source of deterioration of the water quality in the reservoir.

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